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ANTI-CORROSION ALUMINUM ALLOY
[TAISHOKUSEI ARUMINIUMU GOKIN]

SUGURU JIN ET AL

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INVENTOR(S)	(72):	Suguru Jinb Naomi Nishi
APPLICANT(S)	(71):	Ryobi Ltd.
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TITLE	(54):	ANTI-CORROSION ALUMINUM ALLOY
FOREIGN TITLE	[54A]:	TAISHOKUSEI ARUMINIUMU GOKIN

Specification

1. Title of the Invention

Anti-corrosion aluminum alloy

2. What is claimed is:

(1) An anti-corrosion aluminum alloy, characterized in that it contains 4.0 to 6.5 wt% Mg, 1.0 to 2.5 wt% Mn and 0.3 to 1.5 wt% Si, with the balance being Al, < 0.5 wt% Fe, < 0.1 wt% Cu, < 0.1 wt% Ni and < 0.3 wt% Zn.

(2) An anti-corrosion aluminum alloy, characterized in that it contains 4.0 to 6.5 wt% Mg, 1.0 to 2.5 wt% Mn, 0.3 to 1.5 wt% Si, and one or more selected from the group consisting of 0.01 to 0.3 wt% Ti, 0.001 to 0.1 wt% B and 0.01 to 0.3 wt% Zr, with the balance being Al, < 0.5 wt% Fe, < 0.1 wt% Cu, < 0.1 wt% Ni and < 0.3 wt% Zn.

3. Detailed Description of the Invention

[Industrial Applicability]

The present invention relates to an anti-corrosion aluminum die-cast alloy.

[Prior Art]

Conventionally aluminum die-cast alloys, which are based on Al-Si-Cu JIS-ADC10 and ADC12, have been widely used.

The Al-Si-Cu alloys, which have excellent die-casting properties and relatively high strength, are suited to the manufacture of thin castings having an intricate configuration and have previously been used in various fields.

However, due to their poor anti-corrosion properties, it is difficult for these alloys to be applied to shipbuilding parts and exterior construction parts, which are exposed to harsh environments inducing corrosion, and when anti-corrosion properties are required, these alloys must be surface-treated with a coating solution, a metal plating or the like.

Al-Mg based alloys ACD5 and ADC6 have been specified in JIS as anti-corrosion die-cast alloys and have been widely used in castings where anti-corrosion properties are required and as alloys for making Alumite.

The above-described Al-Mg binary alloy has excellent anti-corrosion properties which are similar to pure industrial-use Al, but can be readily seized to dies and, as a result of alloying with Mg, the solidifying temperature range can be expanded to cause cracking and also raise problems with hot fluidity.

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Therefore, ADC6 contains 1 wt% or less Si and a small amount of Mn and Fe in order to improve the castability and strength in practical applications.

Further, ADC5 contains 1.8 wt% or less Fe in order to inhibit the seizing to dies, thereby enabling die-casting.

As described above, in order to improve castability and strength without sacrificing anti-corrosion properties, Al-Mg based die-cast alloys can be put into practical use by containing relatively small amounts of elements, such as Si, Fe and Mn, either independently or in combination.

However, from the standpoint of anti-corrosion properties, these alloys, which have generally low tensile strength, yield strength and modulus as compared with ADC10 and ADC12, can still be used in ornamental parts, such as cases and covers, but the applications to structural materials which require strength may be limited.

[Problem to be Solved by the Invention]

In view of the above-described problems of prior art, the present invention intends to provide an anti-corrosion aluminum alloy, wherein the castability and strength of an Al-Mg binary alloy can be improved by adding Mn and Si, and excellent anti-corrosion properties and high toughness can be obtained by specifying the proportion of Mg, Mn and Si,

thereby expanding the applicability of the anti-corrosion die-cast alloys.

[Means of Solving the Problem]

More specifically, the present invention solved the above-described problems by providing an anti-corrosion aluminum alloy which contains 4.0 to 6.5 wt% Mg, 1.0 to 2.5 wt% Mn, 0.3 to 1.5 wt% Si, with the balance being Al, < 0.5 wt% Fe, < 0.1 wt% Cu, < 0.1 wt% Ni and < 0.3 wt% Zn, and further contains one or more selected from the group consisting of 0.01 to 0.3 wt% Ti, 0.001 to 0.1 wt% B and 0.01 to 0.3 wt% Zr.

[Embodiments]

Embodiments of the present invention are described in greater detail below.

The composition range of a first aspect of the present invention is described.

Mg: 4.0 to 6.5 wt%, Mn: 1.0 to 2.5 wt%, Si: 0.3 to 1.5 wt%, one or more selected from the group consisting of Ti: 0.01 to 0.3 wt%, B: 0.001 to 0.1 wt% and Zr: 0.01 to 0.3 wt%; balance Al and impurities Fe: < 0.5 wt%, Cu: < 0.1 wt%, Ni < 0.1 wt%, and Zn < 0.3 wt%.

The reasons for limiting the proportion of each alloying element mentioned above are as follows.

(1) Mg

The addition of Mg improves the strength and hardness without sacrificing the anti-corrosion properties of the alloy.

If the proportion is 4 wt% or less, a sufficient strength may not be obtained, whereas if the proportion is 6.5 wt% or more, cracks may readily form during casting.

(2) Mn

In an Al-Mg based alloy which has been conventionally used, only a small amount of Mn has been incorporated, but the proportion of Mn in the inventive alloy is relatively high at 0.1 to 2.5 wt%.

The addition of Mn forms Al_6Mn in the alloy, thereby improving the modulus and yield strength, and the anti-corrosion properties can be effectively improved by solubilizing elements which may impair the anti-corrosion properties, such as Fe, in Al_6Mn.

Further, the addition of Mn also prevents the alloy from being seized to dies during die-casting.

If the proportion of Mn is 1 wt% or less, the above-described effects may not be sufficiently obtained, whereas if the proportion exceeds 2.5 wt%, coarse Al_6Mn may be precipitated, resulting in mechanical properties being impaired; therefore, the proportion range of Mn is set to be 1.0 to 2.5 wt%.

(3) Si

Al-Mg based alloys forms cracks during casting and can readily induce cast defects, such as misrun, but the addition of Si can prevent the occurrence of such cast defects. If the proportion is 0.3 wt% or less, the improving effect on the castability may not be sufficiently obtained, whereas if the proportion is 1.5 wt% or more, the amount of Mg_2Si in the alloy increases, resulting in the mechanical properties being impaired; therefore the proportion of Si is preferably in a range from 0.3 to 1.5 wt%.

(4) Ti and B

Coupled with the addition of B, the addition of Ti contributes to a significant improvement in crystal grain refining and is therefore effective on improving the castability.

If the proportion of Ti is 0.01 wt% or less and the proportion of B is 0.001 wt% or less, the above-described effect may not be sufficiently obtained, whereas if the proportion of Ti is 0.3 wt% or more and the proportion of B is 0.1 wt% or more, coarse compounds may be produced, resulting in the toughness being impaired.

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(5) Zr

As well as Ti and B, the addition of Zr refines crystal grains and is therefore effective on improving the castability. If the proportion is 0.01 wt% or less, the above-described effect may not be sufficiently obtained, whereas if the proportion is 0.3 wt% or more, an Al-Zr based compound may be produced, resulting in the toughness being impaired.

[Preparation example]

The inventive alloys and comparative alloys prepared by the present inventors are described in greater detail below.

Alloys having the composition shown in Table 1 were casted in a 90-ton die-cast machine at a casting temperature of 720 to 750 degrees Celsius, at a metal mold temperature of 110 to 160 degrees Celsius, at an injection rate of 1.3 to 1.5 m/sec, at a casting pressure of 190 kg/cm^2 and a curing time of 5 seconds, thereby yielding samples No. 1 to 8.

Separately, JIS standard ADC10 alloy and ACD6 alloy were casted under the same conditions as above in order to obtain comparative alloys.

Table 1

Elements / Alloy No.	Mg	Mn	Si	Fe	Ti	B	Zr	Al	Note
1	4.21	1.33	0.53	0.29	0.10	0.003	-	Bal.	The inventive alloy
2	5.14	1.89	0.96	0.27	0.09	0.003	-	Bal.	The inventive alloy
3	4.20	1.07	0.58	0.29	0.07	0.003	-	Bal	The inventive alloy
4	6.15	2.05	0.35	0.10	-	-	0.11	Bal.	The inventive alloy
5	6.54	2.01	0.62	0.32	-	-	-	Bal.	Comparative alloy
6	7.28	2.06	0.16	0.11	-	-	-	Bal.	Comparative alloy
7	2.93	2.16	0.15	0.18	-	-	-	Bal.	Comparative alloy
8	5.08	2.57	0.13	0.19	-	-	-	Bal.	Comparative alloy
Comparative Alloy ADC 6	2.5 to 4.0	0.4 to 0.6	< 1.0	< 0.8	-	-	-	Bal.	Cu < 0.1, Zn < 0.4, Ni < 0.1, Sn < 0.1
Comparative alloy ADC10	< 0.3	< 0.3	7.5 to 9.5	< 1.3	-	-	-	Bal.	Cu 2.0 to 4.0, Ni < 0.5, Zn < 1.0, Sn < 0.3

The following experiments were carried out using samples No. 1 to 8 and comparative alloys. The results are shown in Table 2 and Table 3.

(1) Observation of solidification structure

The accompanying drawing is a light photomicrograph (×500) of the solidification structure of sample No.1.

The structure consists of an intermetallic compound Al_6Mn phase finely dispersed, Mg_2Si eutectic crystals and an Al matrix in which Mg has been solubilized.

(2) Tensile test

As-cast samples No. 1 to 8 and comparative alloys having a shape according to the ASTM specifications (U.S.) for tensile testing were subjected to a standard tensile test.

(3) Hardness test

As-cast samples No. 1 to 8 and comparative alloys having a size of 6.3 × 6.3 × 10 mm were subjected to standard measurement of Vickers hardness (Hr) under a load of 500 g.

(4) Impact Test

The impact test was carried out using unnotched samples No. 1 to 8 and comparative alloys having a size of 6.3 × 6.3 × 70 mm. The impact test applied was a 5 kg-m Charpy impact testing machine.

(5) Corrosion promoting test

A salt spray test and a salt water exposing test were carried out using samples No. 1 to 4 and comparative alloys having a size of 20 × 10 × 60 mm.

The salt spray test was carried out using 5 wt% NaCl solution according to JIS standard D0201 and the salt water exposing test was carried out using 3 wt% NaCl solution. The corrosion status was evaluated by the rating numbers or corrosion loss.

Table 2

Properties / Alloy No.	Tensile test				Hv hardness (500 g)	Impact value (kgf/cm^2)	Note
	Tensile strength (kgf/cm^2)	Yield strength (kgf/cm^2)	Elongation (%)	(Reference) Elasticity (kgf/cm^2)			
1	30.8	17.8	15.5	7900	83	6.69	The inventive alloy
2	32.7	18.9	10.1	7900	94	3.77	The inventive alloy
3	30.8	17.6	15.7	7900	84	6.10	The inventive alloy
4	34.2	18.4	12.1	6700	118	3.80	The inventive alloy
5	34.5	19.7	8.6	7800	113	3.12	Comparative alloy
6	35.2	20.0	9.5	6900	109	2.45	Comparative alloy
7	26.5	13.9	16.0	7300	90	8.19	Comparative alloy
8	30.2	17.1	8.9	7200	97	4.79	Comparative alloy
ADC6	25.0 to 26.5	11.2 to 14.8	7.5 to 10.0	6870	74	4.5	Reference material
ADC10	30.5 to 32.5	17.6	1.5 to 4.0	7240	80 to 100	0.94	Reference material

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Table 3

Testing time (Hr.) / Alloy No.	Ratings (Rating numbers)						Note
	4	8	24	48	72	96	
1	9.8	9.5	9.5	9.3	9.0	9.0	The inventive alloy
2	9.8	9.8	9.5	9.3	9.0	9.0	The inventive alloy
3	9.8	9.5	9.5	9.3	9.0	9.0	The inventive alloy
4	9.8	9.5	9.3	9.0	9.0	8.5	The inventive alloy
ADC6	9.3	9.0	8.5	8.0	7.0	7.0	Reference material
ADC10	4	2	-	-	-	-	Reference material

Table 4

(Corrosion loss g/m^2)

Alloys / Period	No. 1 (The inventive alloy)	ADC6 (reference material)
4 weeks (672 Hr)	178	245

As is clear from the results shown in Table 2, the inventive alloys were found to have the same level of tensile strength, yield strength and hardness, with the elongation and impact value being 3 to 9 times those of the ACD10.

By contrast, comparative alloys of which the composition was outside the range specified by the present

invention were found to have low elongation and toughness in the case where the proportion of Mg, Mn or Si was excessive and to have insufficient strength and yield strength in the case where the proportion of Mg or Mn was insufficient.

As shown in Table 3 and Table 4, the anti-corrosion properties of the inventive alloys were the same as or higher than the ADC6, indicating that the inventive alloys have better anti-corrosion properties than conventional die-cast alloys.

[Effect of the Invention]

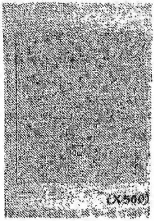
As described above, since the inventive anti-corrosion aluminum alloy has improved tensile strength and yield strength as compared with conventional anti-corrosion aluminum die-cast alloys and also has excellent anti-corrosion properties, the inventive anti-corrosion aluminum alloy is suitable as a cast for shipbuilding parts and exterior construction parts which require strength and anti-corrosion properties.

4. Brief Description of the Drawings

The accompanying drawing is a light photomicrograph of the solidification structure of sample No.1 casted by the inventive alloy.

Applicant: Ryobi Ltd.

Hiroshi Urakami, President director



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Amendment of Proceedings

12/2/1988

Commissioner:

1. Identification of the Case

   Japanese Patent No. 225077 (1987)

2. Title of the Invention

   Anti-corrosion aluminum alloy

3. Person Filing Amendment

   Relationship to case: Applicant

   Address: 762 Mesaki-cho, Fuchu-shi, Hiroshima

   Applicant Name: (694) Ryobi Ltd.

   Hiroshi Urakami, President director

4. Date of Amendment Directive

   Voluntary amendment

6. Object for Amendment

(1) Item “What is claimed is” in Specification

(2) Item “Detailed Description of the Invention” in Specification

7. Contents of Amendment

The details are given on the attached sheet.

Contents of Amendment:

(1) The items in “What is claimed is” in Specification are amended as follows.

(1) An anti-corrosion aluminum alloy, characterized in that it contains 4.0 to 6.5 wt% Mg, 1.0 to 2.5 wt% Mn and 0.3 to 1.5 wt% Si, with the balance being Al and incidental impurities < 0.5 wt% Fe, < 0.1 wt% Cu, < 0.1 wt% Ni and < 0.3 wt% Zn.

(2) An anti-corrosion aluminum alloy, characterized in that it contains 4.0 to 6.5 wt% Mg, 1.0 to 2.5 wt% Mn, 0.3 to 1.5 wt% Si, and one or more selected from the group consisting of 0.01 to 0.3 wt% Ti, 0.001 to 0.1 wt% B and 0.1 to 0.3 wt% Zr, with the balance being Al and incidental impurities < 0.5 wt% Fe, < 0.1 wt% Cu, < 0.1 wt% Ni and < 0.3 wt% Zn.

(2) The items in “Detailed Description of the Invention” in Specification are amended as follows.

1) Amendment: “Al-Mg binary alloy” appeared in page 2 line 17 and page 4 line 1 as “Al-Mg based die-cast alloy”.

2) Amendment: "a small amount of Mn and Fe" appeared in page 3 lines 2 and 3 as "0.4 to 0.6 wt% Mn and 0.8 wt% or less Fe".

3) Amendment "from the standpoint of anti-corrosion properties, the alloys" appeared in page 3 line 13 as in "the alloys which focus on anti-corrosion properties".

4) Amendment: "and < 0.5 wt% Fe" appeared in page 4 line 11 as "and incidental impurities < 0.5 wt%".

5) Deleted: "the composition range of a first aspect of the present invention is described" appeared in page 4 line 19.

6) Amendment: "impurities" appeared in page 5 line 3 as "incidental impurities".

7) Amendment: "and Zn < 0.3 wt%." appeared in page 5 lines 4 to 5 as in "Zn < 0.3 wt% for constituting the present invention".

8) Amendment: "or less" appeared in page 5 line 10, page 6 line 4, line 12, line 19 and page 7 line 5 as "less than".

9) Amendment: "or more" appeared in page 5 line 11, page 6 line 13, line 20 and page 7 line 5 as "exceeding".

10) Amendment: "relatively high at 0.1 to 2.5 wt%" appeared in page 5 line 16 as "relatively high at 1.0 to 2.5 wt%".

11) Amendment: typo "range" in Japanese appeared in page 6 line 15.

12) Inserted: the following lines between lines 15 and 16 in page 6.

(4) Fe

Fe forms Al_6Fe in the grain boundary when the alloy is solidified and therefore impairs the anti-corrosion properties and toughness. However, conventional Al-Mg based die-cast alloys positively contain Fe in order to prevent the alloy being seized to dies.

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By contrast, in the inventive alloy, by the relatively high proportion of Mn in the alloy, it is not necessary for Fe to be positively added in order only to prevent the alloy from being seized to dies; therefore, the permissible proportion of Fe is less than 0.5 wt% as an incidental impurity.

(5) Cu, Ni, Zn

Cu and Ni significantly impair the anti-corrosion properties and therefore the permissible proportion thereof is limited to be less than 0.1 wt%.

The anti-corrosion properties are not greatly affected by the addition of Z, but if the proportion is too high, Zn_2Mg may be precipitated, resulting in the anti-corrosion properties being impaired; therefore, the proportion of Zn is set to be less than 0.3 wt%.

13) Amendment: "(4) Ti and B" appeared in page 6 line 16 as "(5) Ti and B".

14) Amendment: "(5) Zr" appeared in page 7 line 2 as "(6) Zr".

15) Amendment: "190 kg/cm^2" appeared in page 7 line 13 as "760 kgf/cm^2".

16) Amendment: "samples No. 1 to 8" appeared in page 7 line 14, page 8 line 7 from the bottom, page 9 lines 3 to 4, and page 9 line 7, line 11 and line 12 as "samples No. 1 to 9".

17) Amendment: Table 1 appeared in page 8 as follows.

(space)

Table 1

Elements / Alloy No.	Mg	Mn	Si	Fe	Ti	B	Zr	Al	Note
1	4.21	1.33	0.53	0.29	0.10	0.003	-	Bal.	The second inventive alloy
2	5.14	1.89	0.96	0.27	0.09	0.003	-	Bal.	The second inventive alloy
3	4.20	1.07	0.58	0.29	0.07	0.003	-	Bal	The second inventive alloy
4	6.15	2.05	0.35	0.10	-	-	0.11	Bal.	The second inventive alloy
5	4.18	1.40	0.54	0.23	-	-	-	Bal.	The first inventive alloy
6	6.54	2.01	0.62	0.32	-	-	-	Bal.	Comparative alloy
7	7.28	2.06	0.16	0.11	-	-	-	Bal.	Comparative alloy
8	2.93	2.16	0.15	0.18	-	-	-	Bal.	Comparative alloy
9	5.08	2.57	0.13	0.19	-	-	-	Bal.	Comparative alloy
Comparative Alloy ADC 6	2.5 to 4.0	0.4 to 0.6	< 1.0	< 0.8	-	-	-	Bal.	Cu < 0.1, Zn < 0.4, Ni < 0.1, Sn < 0.1
Comparative alloy ADC10	< 0.3	< 0.5	7.5 to 9.5	< 1.3	-	-	-	Bal.	Cu 2.0 to 4.0, Ni < 0.5, Zn < 1.0, Sn < 0.3

18) Amendment: "Vickers hardness (Hr)" appeared in page 9 line 8 as "Vickers hardness (Hv)".

19) Amendment: "5 kgm" appeared in page 9 line 13 as " 5 kg.m".

20) Amendment: “samples No. 1 to 4” appeared in page 9 line 16 as “samples No. 1 to 5”.

21) Amendment: typo “rating numbers” in Japanese appeared in page 9 line 20.

22) Amendment: Table 2 appeared in page 10 as follows.

(space)

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Table 2

Properties / Alloy No.	Tensile test				Hv hardness (500 g)	Impact value (kgf/cm^2)	Note
	Tensile strength (kgf/cm^2)	Yield strength (kgf/cm^2)	Elongation (%)	(Reference) Elasticity (kgf/cm^2)			
1	30.8	17.8	15.5	7900	83	6.69	The second inventive alloy
2	32.7	18.9	10.1	7900	94	3.77	The second inventive alloy
3	30.8	17.6	15.7	7900	84	6.10	The second inventive alloy
4	34.2	18.4	12.1	6700	118	3.80	The second inventive alloy
5	31.2	17.9	15.1	7900	84	6.51	The first inventive alloy
6	34.5	19.7	8.6	7800	113	3.12	Comparative alloy
7	35.2	20.0	9.5	6900	109	2.45	Comparative alloy
8	26.5	13.9	16.0	7300	90	8.19	Comparative alloy
9	30.2	17.1	8.9	7200	97	4.79	Comparative alloy
ADC6	25.0 to 26.5	11.2 to 14.8	7.5 to 10.0	6870	74	4.5	Reference material
ADC10	30.5 to 32.5	17.6	1.5 to 4.0	7240	80 to 100	0.94	Reference material

23) Amendment: Table 3 appeared in page 10 as follows.

Table 3

Testing time (Hr.) / Alloy No.	Ratings (Rating numbers)						Note
	4	8	24	48	72	96	
1	9.8	9.5	9.5	9.3	9.0	9.0	The second inventive alloy
2	9.8	9.8	9.5	9.3	9.0	9.0	The second inventive alloy
3	9.8	9.5	9.5	9.3	9.0	9.0	The second inventive alloy
4	9.8	9.5	9.3	9.0	9.0	8.5	The second inventive alloy
5	9.8	9.8	9.5	9.3	9.0	9.0	The first inventive alloy
ADC6	9.3	9.0	8.5	8.0	7.0	7.0	Reference material
ADC10	4	2	-	-	-	-	Reference material

Applicant: Ryobi Ltd.